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# Meta intended learning outcome alignment in experimental course planning

## Taking control of a week of experimental course work

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Introduction to institutional teaching of new University teachers often occurs in the context of previously established courses. Integration of new teachers into the curriculum by means of roles in established courses can be mutually beneficial. Existing courses can benefit from integrating new teachers, for example by refreshing course content and incorporating teaching enthusiasm of junior faculty. New teachers also benefit as they obtain the ability to interact with students earlier than they could if they created new courses. The addition of new courses to the study curriculum requires careful consideration and can thus be a lengthy procedure. The curricula are often crowded, which can also result in low uptake of new courses by students. Furthermore, the integration into new courses offers the opportunity for new faculty to align their course content with pedagogically well-vetted teaching by peer-to-peer feedback. This exercise can reinforce benefits for existing courses, as cutting-edge pedagogical teaching concepts that are offered to new faculty as a result of the elite university pedagogy course can be applied to holistically reinvigorate the courses across the board. A challenge for the inclusion of new faculty into existing courses can be to align the broad intended learning outcomes of the entire course (meta-ILOs), with blocks taught by new faculty that may have self-sufficient contents and ILOs (sub-ILOs). The Possibility to align the sub-ILOs of individual teaching blocks with broader course meta-ILOs specified in existing course descriptions is instrumental for a modular teaching arrangement such at Copenhagen University with limited curricular space for entirely new courses. This paper applies constructivist learning theory to a selfcontained teaching module of an experimental course, while aligning the course content to meta-ILOs.

## Background

Teaching defines the complex pedagogical and didactical activities by a teacher to assist student learning. Learning of complex skills or information can be incidental (e.g riding a bike), which is referred to as implicit learning. Implicit learning has undisputed effects on knowledge; however University teaching tends to avoid course designs emphasizing this type of learning. Implicit learning tends to generate pieces of abstract knowledge without necessarily clarifying the underlying thought patterns that may make more general thought patterns difficult to apply to address related questions. University teaching aims for “deep learning” of context, perspectives and knowledge. This desired learning outcome of University teaching has led to a reflection on the role of teaching in learning. Figure 18.1 illustrates how teaching is affected by the elements of teaching, making up the didactic triangle: students, content and the teacher. Through emphasis on different interfaces between the elements distinct yet mutually overlapping theoretical frameworks for teaching have been developed.

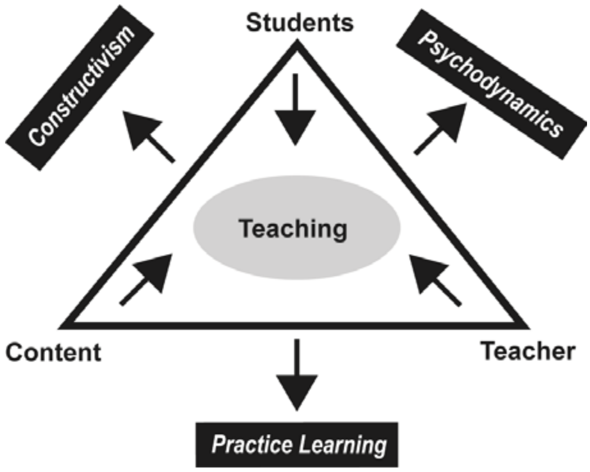


Fig. 18.1: The Didactic Triangle connects the three main elements of teaching: students, teacher and content learning (adapted from Rienecker, Jørgensen, Dolin, and Ingerslev, 2015). Different approaches to teaching are illustrated that emphasize interfaces of teaching elements. KU teaching encourages constructivism, where teachers facilitate of the students' independent content learning.

Psychodynamic learning theories highlight the interplay between teacher and student. The creation of a good learning environment and relationships is central, whereas the content is given a peripheral role. A strong intellectual bond between student and teacher can intensify learning, and good relations between students and teacher have clear positive effects on learning and career development. A psychodynamic approach can facilitate learning through the role-models, with a focus on student self-efficacy (Bandura, 1997). Effective psychodynamic teaching approaches rely on a strong intrinsic attraction of teacher and students to the content.

Practice learning theory focuses on the interaction of the teacher with the content. A teacher's expertise of the content is communicated to students by demonstrations and lecturing. The teacher adopts the role of an authority in the subject, and may instruct students to follow the example set by the procedures and contextual understanding of the teacher. Particularly for teaching skills this teaching method can be effective with small classes, however in general the students adopt a rather peripheral role that may trigger disinterest. Practice learning can be an effective way to teach best working procedures, however students may not comprehend the thought processes that had been going into the procedure development and may not be able to evaluate them contextually.

Constructivist learning theory focuses on the interface of student and content. This necessitates active participation of students with the content, and facilitating their individual or collective journey to knowledge. Teachers following constructivist learning theories rely on student activities to construct their own knowledge. The importance to incentivize active participation in the teaching cannot be underestimated, as taken to the extreme the teacher merely assists a self-driven generation of knowledge and learning by the students. If used incorrectly, this teaching theory can give students the feeling of being ignored, lead to a focus on peripheral topics or perhaps even using incomplete if not incorrect information to construct their knowledge. Constructivist teaching relies on measured interventions and restraint form the teacher to allow students the freedom to learn from their own mistakes. This freedom of students is constraint by the realities of University teaching that impose limiting regulations on: course hours, program durations, funding and equipment accessibility.

The benefits of constructivist learning include an empowerment of students to create their own knowledge based on their interest and reflection on the subject matter. This self-driven interest may go beyond limits defined by a course design that may be more focused on the communication of maximally simplified subject content in a non-specialist course. The mature treatment of student individuality and student group activities as key parts of the constructivist learning theory makes this approach to learning attractive to university teaching. To provide a framework for feedback on learning for students, and to align learning activities with their desired effects the assessment serves a crucial role in constructivism. This feat is achieved by Constructive Alignment, whereby the instruments and intentions of a course design are coordinated to effectively promote self-driven knowledge creations of students (Figure 18.2). Feedback opportunities integral to the assessment guide students, but also improve courses by allowing cutting-edge pedagogical innovations and new topics to be incorporated.

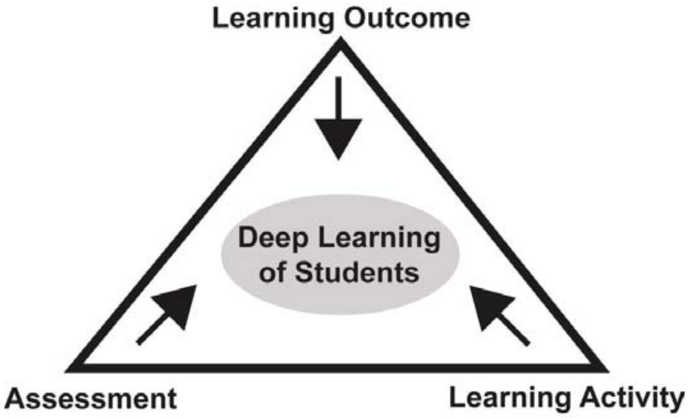


Fig. 18.2: Graphical summary of how the coordination of learning outcomes, learning activities and assessment conditions effective student learning (adapted from Rienecker, Jørgensen, Dolin, and Ingerslev, 2015). An effective coordination of the activities in the corners of the triangle aids deep learning (Biggs, 1987), and represents the core of the Constructive Alignment model (Biggs and Tang, 2007).

The course description for courses at Copenhagen University includes a definition of Intended Learning Outcomes (ILOs), the type of learning activity and how learning is assessed. The course description for NPLB15008U: Thematic Course: Experimental Molecular Biology I is given in Appendix A. A more detailed look at the course structure reveals it's segmentation in 8 blocks of a week each on certain themes related to the broad topic. The blocks are taken over by different teachers that define ILOs (sub-ILOs) for the topic covered in the block. To create a framework for constructivist student learning it is of crucial importance that the sub-ILOs are aligned with the ILOs of the entire course (meta-ILOs). Important insight into the level of student learning can be derived from usage of the Structure of the Observed Learning Outcome (SOLO) taxonomy used in courses with following a constructivist learning theory. The taxonomy evaluates the structure of layered student learning in categories assigning degrees of content conceptualization and understanding (Figure 18.3).

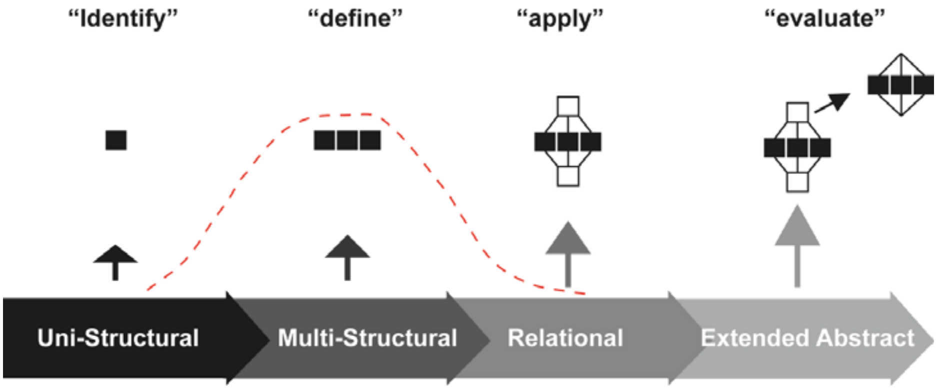


Fig. 18.3: Illustration of Structure of the Observed Learning Outcome (SOLO) taxonomy (Biggs and Tang, 2007, learning (adapted from **Rienecker15**). The illustration conceptualizes increasingly complex levels of understanding. The SOLO taxonomy represents a continuation of Bloom's taxonomy of learning objectives (Bloom, 1956). The red line represents the expected distribution of student learning level, with a focus on multi-structural learning, based on experience and SOLO taxonomy used in Appendix A.

One of my newly adopted teaching opportunities at Copenhagen University is to plan and organize the second module (module B) of 8 total modules in this experimental course. The topic of module is "RNA detection", which fits well to the defined meta-ILOs. To ensure a stable constructivist learning environment for students my role as module responsible is to align the sub-ILOs to my module to the meta-ILOs in the course description. The course is very popular with students, as it offers them the opportunity to conduct lab work in a research environment; however it aims at pre-BSc level students that often have little prior experimental knowledge. The level of prior student content familiarity and understanding is evident from the course description in appendix A, as it key verbs following SOLO taxonomy indicative of the student learning structures have been employed. Hence we should expect a student population with mainly multi-structural learning (red line, Figure 3). My function as theme organizers brings autonomy of the academic content, the learning & teaching activities and perspectives. As I am functioning as part of a larger team of theme organizers, it is crucial to coordinate two other important factors to ensure a stable and coherent constructivist learning framework for students. These two additional factors under some constraint for theme organizers are: the sub-ILOs and the Purpose & Content. Constraint on the sub-ILOs is given by the overarching meta-ILOs defined in Appendix A. Restrictions on the Purpose and Content is given by the choice of theme, in my case “RNA detection”. It is the expectation of fellow teacher colleagues that I teach on the topic of “RNA detection, similarly, students expect to learn about the topic. Even though the topic of “RNA detection” is broad and leaves plenty of freedom to choose the exact academic content, some level of constraint is represented by giving students the opportunity to learn about RNA.

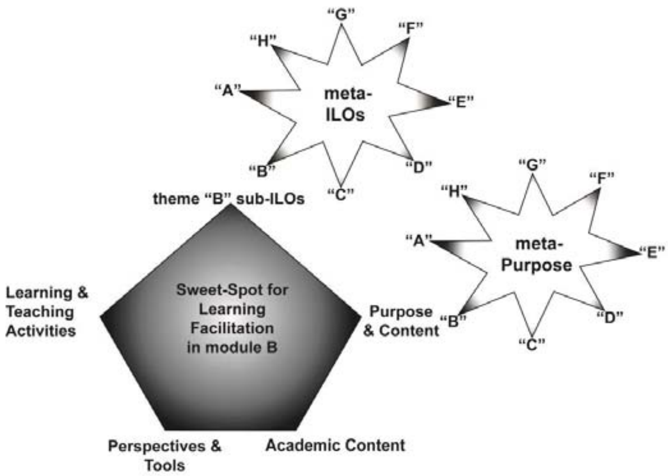


Fig. 18.4: Pedagogical Pentagram model for advanced course planning learning (adapted from **Rienecker15**). The diagram illustrates how multiple parameters influence how student learning is best facilitated by their teacher. NPLB15008U: Thematic Course: Experimental Molecular Biology I is structured in themes in 8 themes A-H. The 8-ended stars illustrated how the substructure of each individual theme in A-H is influenced by the meta-structure of the course. This applies in particular to the ILOs and the Purpose & Content edges of the Pedagogical Pentagram.

## Defining meta-ILOs consistent sub-ILOs for “theme B: RNA detection”

To adapt to the general course requirements and teaching vision of the course, the ILOs of theme B: RNA detection (sub-ILOs) have to be consistent with the ILOs of the entire course (meta-ILOs). This consideration applies to the content, but also to the SOLO taxonomy adjusting ILOs to the expected types of student learners. Table 18.1 summarizes the Academic content, teaching activities & tools and sub-ILOs. The SOLO taxonomy anticipates uni-structural, multi-structural and relational learners. The meta-context of the course places theme B: RNA detection just after theme: A cloning, where an emphasis is on DNA. On day 1 of the course we will draw on the knowledge on DNA of the students, and incorporate a comparison of DNA and RNA molecules to hydrolysis. The analysis tools and methods will give students a different perspective on the focus biomolecules of the themes, and serve as reinforcement of meta-ILOs by building on learning in theme A. The duration of student time in the lab is fairly short, considering the activities have to be coordinated with up to 60 students split in two teaching labs. The sub-ILOs and academic content spans an experiment as it would be common in a research setting. We provide perspective on how these experiments are topically relevant to the students by organizing a journal club related to an exciting development in the field of RNA Biology.

Table 18.1: Planning Experimental Biology BSc course, theme "B RNA detection". The columns represent the corners of the pedagogical pentagram. The sub-ILOs of "theme B RNA detection" are given using SOLO nomenclature aligned with the appropriate stages of student learning, ranging from uni-structural to relational (see Figure 18.4).

| | **Academic Content** | **Teaching Activities & Tools** | **sub-ILOs** |
|---|---|---|---|
| **day B1** | Handling Biological material for RNA preparation | Yeast wild type and rrp6Δ RNA decay pathway mutant material | Identify strains related to accompanying Journal Club |
| | RNA peparation | RNA handling and preparation | Define working procedures with RNA |
| | Measure RNA concentration | UV-VIS spectrometry of nucleic acids | Mark RNA concentration from spectral data |
| | Stability of RNA vs DNA | Hydrolysis of RNA and DNA | Relate RNA working procedure with stability differences compared to DNA |
| | TBE Agarose Gel Electrophoresis | TBE Gel preparation | Define characteristics of TBE Agarose gel electrophoresis |
| **day B2** | Visualize fragmentation of RNA vs DNA using TBE gel-electrophoresis | Perform ATBE garose Gel Electrophoresis | Apply TBE Agarose gel electrophoresis |
| | RNA fragmentation, polyA-selection | Purification of cellular RNA populations | Define RNA populations |
| | Reverse-Transcription | Conversion of RNA into complementary DNA | Identify strategies to convert RNA into cDNA |
| **day B3** | Experimental design of qPCR plate | Design of quantitative RT-PCR experiment | Mark qPCR plate design |
| | qPCR plate pipetting following design | Experimental design in 384-well plate format | Apply qPCR plate design |
| | qPCR run | qPCR machine software, run parameters | Describe processes ensuring qPCR run |
| **day B4** | qPCR pipetting, run | Experimental design in 384-well plate format | Apply qPCR plate design and run |
| | qPCR data handling | Analysis of experimental qPCR data | Describe qPCR data analysis strategies |
| | results summary | Discussion of results | Analyze qPCR |

The journal club takes place early, in the morning of the 2nd course day prior to lab work. It provides a different angle for students to engage with the subject. They can prepare by reading cutting-edge literature in the time between courses unlimited from constraining course hours. The biological material analyzed in the research paper will be familiar to the students: on the 1st day, students will receive the equivalent biological material. It is our intention that the connection between lab reality and featuring of the same material in a research paper may help students relate with the provided literature and trigger their deeper interest in the topic. The progression of theme B will allow students to perform quantitative analysis of RNA species. The analysis will span different biological backgrounds, but also sub-populations of RNA from the cell by means of specific enrichment via molecular features. The analysis part will interest students, as they are given the opportunity to compare real experimental results. A central part will be devoted to the analysis of the data, and students are encouraged to explore and compare analysis methods. This comparison will feature a discussion about research ethics, as outliers in the data are expected. The teachers of theme B will submit questions for the assessment, and correct the reports. These activities alongside course feedback by the students will help to align student and teacher expectations in iteratively. One hour in the morning of a subsequent course week will bring the teachers together with the students again, where reports should be more complete and a reflection on the results can be stimulated.

## Summary

The course structure at KU somewhat constrains the speed of which new courses can become favorite choices of students in their curricula. Students are nevertheless given the opportunity to learn from teaching of new faculty that may possess expertise on new topics complementary to existing courses. The cutting-edge expertise and enthusiasm of labs new to KU teaching will be unlocked for the course by involving them in course design and as teachers. The constructivist teaching approach with sub-ILO and meta-ILO structures facilitates the participation in existing courses seamlessly, and possible more time efficiently than otherwise possible. Iterative cycles of constructive alignments as integrated part of the course assessments will progressively align pedagogical approaches and content to allow deep student learning. Research teams new to KU benefit from taking part in teaching of already popular courses in the curriculum. Teaching involvement facilitates student interactions and exposure to upcoming research topics often represented by new research groups at KU can provide new career and learning opportunities for KU students. Laboratory research has some inherent psychodynamic aspects, as researchers share an often small laboratory space, where a good atmosphere and working relations are important. Students engaged in laboratory learning and research settings are also given the opportunity to reflect on if the atmosphere of a new group of KU teachers involved in teaching could stimulate their joy of learning. If a new research group was not involved in teaching, the students would be deprived of this opportunity. All in all new teaching faculty provides an important source for course innovations, however owing to a common constructivist teaching philosophy the integration of new teachers in existing course is greatly facilitated, which ultimately is of benefit to new and established teachers as well as the students.

## References

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## A Course Description of NPLB15008U Thematic Course: Experimental Molecular Biology I

**Education:** BSc Programme in Biology-Biotechology

**Content**:
The course offers experimental platforms to acquire new skills with regard to methods in molecular biology and biotechnology. The choice of topics ensures that the students learn standard techniques relevant to molecular biology, bioinformatics, biochemistry and physiology. Additionally, the course comprises an introduction to basic concepts of ethics and philosophy of science.
The students will gain experiences in a wide-range of both basic and advanced experimental methods in molecular biology, e.g. extraction of DNA and RNA, PCR, RT-PCR, real-time PCR, in-situ hybridization, cloning, primer and vector design, transformation of prokaryotic and eukaryotic organisms, cultivations of cell cultures, heterologous gene expression, protein purification, immuno blotting, histochemical analyses, enzyme kinetics, flow cell cytometry, bioimaging and bioinformatics. A wide-range of experimental organisms is employed including bacteria, yeast, fungi, plants and mammalian cells, with an emphasis that the methods and basic scientific principles taught have general relevance.

**Learning Outcome:** The course mainly aims at providing both practical experience and theoretical knowledge of basic principles and methods in experimental molecular biology research in combination with an introduction to general concepts of ethics and philosophy of science within the field.

**After completing the course the students should be able to:**
**Knowledge:** Describe basic principles and analytical methods used in molecular biology research. Explain how these principles and methods can be exploited in practical experiments aimed at reaching distinct research goals.
Describe basic theoretical aspects of scientific research methodology.
Describe selected central principles of ethics philosophy of science.

**Skills:**

Carry out experiments using a number of general methods in molecular biology, biochemistry and cell biology.
Analyse, interpret and conclude from results acquired in the laboratory.
Summarise and present scientific concepts and own research results to fellow scientists through written and oral communications.
Interpret and discuss research in the context of theoretical and ethical principles. Use e.g IT tools in creative processes in the context of project management and presentation.

**Competences:** Work independently as well as together with other students to plan carry out defined experimental work.
Reflect upon the empiric basis of research within the field of biotechnology and understand and contribute to broader ethical and societal discussions on the use of biotechnology.

**Literature:**
Laboratory manuals including theoretical background for each practical exercise is made available on Absalon together with the research articles discussed in the journal clubs and a compendium for ethics and biotechnology. The literature changes from year to year dependent on the chosen topics.

**Teaching and learning methods:**
The course comprises lab exercises with written lab reports, lectures and journal clubs. The students carry out different experiments as specified in the description of the exercises(typically in the afternoon from 1pm to ca. 5pm although this may vary). The results of the exercises are discussed in follow-up sessions. The exercises are complemented by lectures and journal clubs in the mornings (3-4 days per week) which provide the theoretical background for the experiments.

**Academic qualifications:**
Participation in courses which provide basic knowledge in biochemistry and molecular genetics is required.

**Exam:** Credit 15 ECTS, Type of assessment: Written examination, 4 hours under invigilation.

Exam topics include theories and methods taught in practical exercises, journal club articles and philosophy of science curriculum.

Exam registration requirements: 5 out of 7 reports must be accepted in order to be eligible for the exam.

Aid: All aids allowed Marking scale: 7-point grading scale Censorship form: External censorship

Re-exam Reexamination is an oral examination, 30 min. If the exam registration requirement is not met, the student has to follow the course the following year as the laboratory exercises need to be followed. Criteria for exam assesment

Exam topics include theories and methods taught in practical exercises, journal club articles and philosophy of science curriculum.

All contributions to this volume can be found at:

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